Ministry of Transportation
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1991 REPORT ON BRIDGE DECK WATERPROOFING

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

1991

REPORT ON

BRIDGE DECK

WATERPROOFING

BY

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ENGINEERING MATERIALS
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SUMMARY

In 1991, the Ministry of Transportation monitored the thickness of waterproofing membrane placed on bridges under its authority, as well as the quality of the membrane.

Membrane thickness is controlled by an end result specification (ERS) which was introduced in 1986. This specification was expanded in 1987 to include membrane quality.

This report contains a summary of the data assembled and comments on the level of compliance with specified tolerances. Comparison is also made to data of previous years.

Problems with contract administration, improper compiling of "Waterproofing Membrane Thickness Report" forms and "Concrete Product Field Sample Sheets" are discussed.

From an analysis of the contained data, it is concluded that membrane thickness compliance is the highest since the introduction of ERS with 98.6% of all lots attracting full payment on the basis of the original assessment.

Compliance to material quality requirements is unacceptable with 16% of all samples failing one or more tests.

One manufacturer accounted for 78% of all the failures. Deferred testing due to staff shortages resulted in a significant quantity of this product being used on Ministry projects before the problem was discovered. Subsequently, a moratorium was imposed on its use. Had it not been for this particular product, the failure rate would have been within acceptable limits. i.e. < 5%.

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1 INTRODUCTION

1.1 Acceptance Criteria

Bridge deck waterproofing is accepted under an "end result specification" (ERS). This ERS provides for a price reduction or rejection for work which fails to meet specified requirements for material thickness and quality. The thickness component of this ERS was first implemented in 1986 after a three-year interim acceptance system which introduced the principles of ERS. The quality component was added in contracts awarded after September 1987.

1.2 Material Thickness

For 1991, the Concrete Section of the Engineering Materials Office received 222 waterproofing thickness reports from across the Province, representing 77,459.3 m^2 of waterproofing. This area is down 36% from the area waterproofed in 1990 but there remains a significant area of new, and as yet, unwaterproofed bridge decks in the Highway 400 and 407 interchange. These decks will be waterproofed as part of upcoming contracts. The data from each report was entered on a micro computer spreadsheet. The micro computer was used to sort, analyze and graphically depict the accumulated data.

1.3 Material Quality

The Concrete Section tested 225 samples of hot applied, rubberized asphalt waterproofing membrane in 1991. Four of these samples were from other than Ministry contracts. This represents a 29% decrease from the number of samples tested in 1990. These samples represent products from five manufacturers as submitted from contract job sites. The samples were obtained from the contractor's melting kettle, by the contractor, at a time determined by the inspector, so as to be representative of material placed on the bridge deck.

Most of the samples were received in four-litre cans, some in concrete cylinder moulds and a few in individual one-litre cans. Four-litre cans are preferred. In most cases, the required four litres were not supplied which can preclude re-testing of a failed sample if requested by a contractor. The "Concrete Products Field Sample Sheets" accompanying the samples rarely had all the required documentation as enumerated in the "Field Guide For Acceptance Of Hot Mix and Bridge Deck Waterproofing".

The samples were tested for compliance with six specification requirements:

1. Cone Penetration	@ 25°C	max.	110	(0.1 mm)
2. Cone Penetration	@ 50°C	max.	160	(0.1 mm)
3. Flow	@ 60°C	max.	3	(mm)
4. Low Temperature Flexibility	@ -25°C		Pass	
5. Toughness		min.	5.5	(Joules)
6. Toughness/Peak Load Ratio		min.	0.040	

The test results were entered on a micro computer spread sheet program.

2 DATA ANALYSIS

2.1 Material Thickness

Of the 222 lots reported, three were borderline and none were rejectable on the basis of the original testing. (Refer to Provincial Highways report EM-79 for acceptance criteria.) Two borderline lots constructed by one contractor had price adjustment factors of 0.99 and the one borderline lot constructed by another contractor received a price adjustment factor of 0.76.

The average thickness and standard deviation of membrane have remained virtually the same over the last five construction seasons. The average thickness is very close to the target of 5 mm and the standard deviation reflects acceptable process control. Table 1 depicts the thickness statistics from 1984 to 1991.

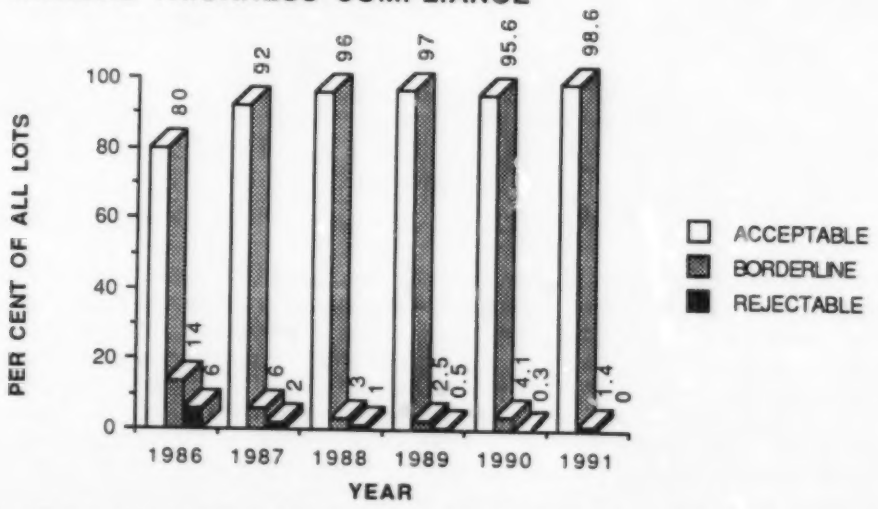
TABLE 1: ANNUAL MEMBRANE THICKNESS SUMMARY

YEAR	NO. OF LOTS	MEAN THICK. (mm)	AVG. LOT ST. DEV.
1984	261	4.7	0.75
1985	306	4.8	-
1986	157	4.9	0.70
1987	254	4.9	0.63
1988	319	4.9	0.63
1989	189	4.9	0.63
1990	341	4.9	0.64
1991	221	4.9	0.63

The larger number of lots for 1985 and 1988 is due to the waterproofing of the new and rehabilitated Burlington Bay Skyway bridges respectively, each of which had 75 lots. The increase in 1990 is the result of the expanded five-year capital programme with construction of many new structures as well as structure rehabilitation projects. It was expected that a similar area would be waterproofed in 1991 but the new bridges at Highway 400 and 407 with a significant surface area, have not yet been waterproofed.

In 1986, only 80% of all the lots constructed were acceptable based on the original assessment whereas 98.6% were found acceptable In 1991. Figure 1 depicts the yearly achievement.

FIG. 1: ANNUAL THICKNESS COMPLIANCE



Eight waterproofing contractors shared the work in 1991 but only five of them waterproofed more than 10,000 m^2. Twelve contractors shared the work in 1990. Figure 2 demonstrates how the work was divided between the contractors. Of the eight contractors, six had all lots accepted at full price, two had borderline (three lots total) and none had a rejectable lot. Figure 3 depicts the relative performance of each contractor (identities concealed).

Individual contractors' statistics are presented in the appendix.

FIG. 2: CONTRACTOR'S SHARE OF WORK

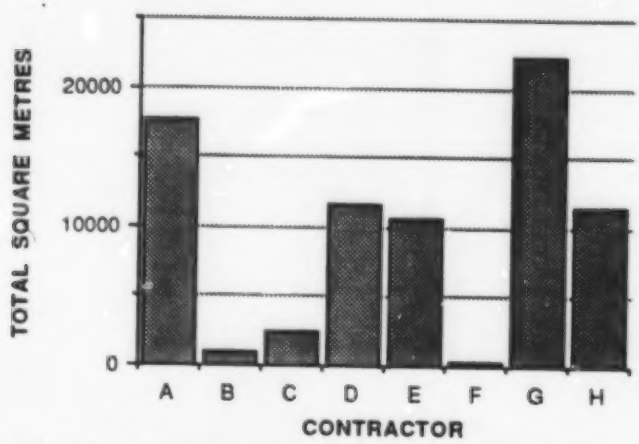
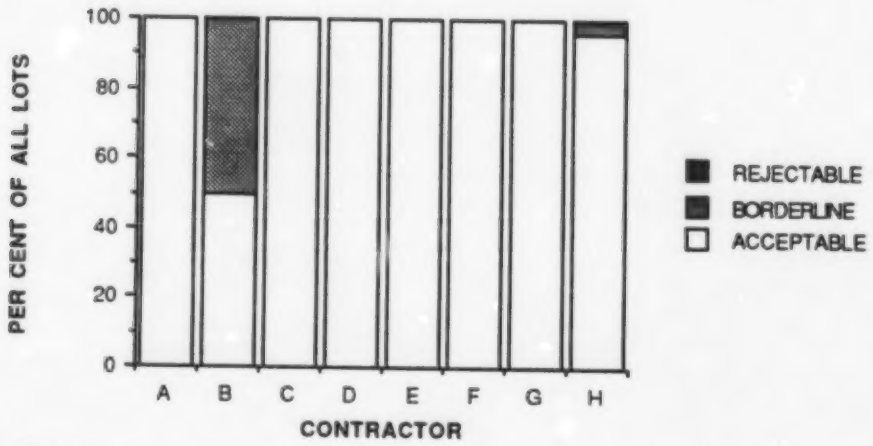


FIG. 3: CONTRACTOR PERFORMANCE (MATERIAL THICKNESS)



2.2 Material Quality

Two hundred twenty five quality assurance samples, representing material from five manufacturers, were tested in the Downsview laboratories. Eighty four per cent of the samples met all test criteria with 16% failing one or more of the quality tests. Thirty seven samples failed, resulting in a price reduction for thirty six lots. The remaining failed sample was from another authority's project. Failures occurred in four of the six quality criteria; only the flow and cone penetration at 25°C requirements were consistently met. Figures 4 and 5 demonstrate the proportions of samples failing tests. The Price Adjustment Factors ranged from a low of 0.900 to a high of 0.995 with an average of 0.955. Figure 6 demonstrates the distribution of the five manufacturers' products on Ministry work. Individual manufacturers' statistics are contained in the appendix.

FIG. 4: FIVE YEAR HISTORY OF QUALITY TESTS

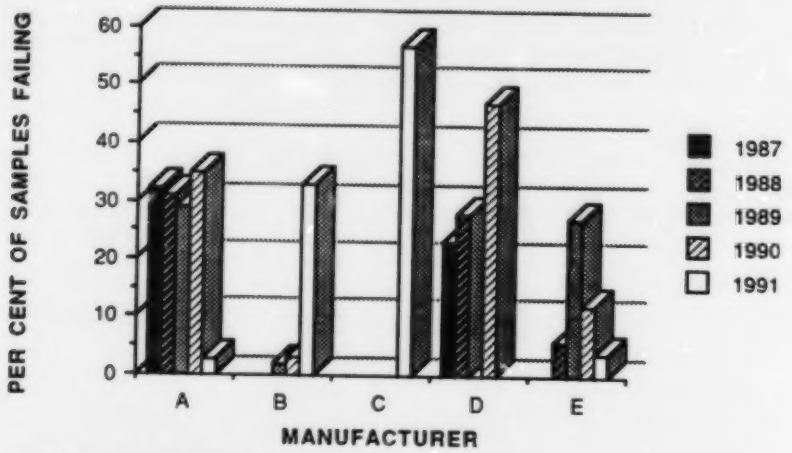


FIG. 5: TEST CRITERIA FAILED IN 1991

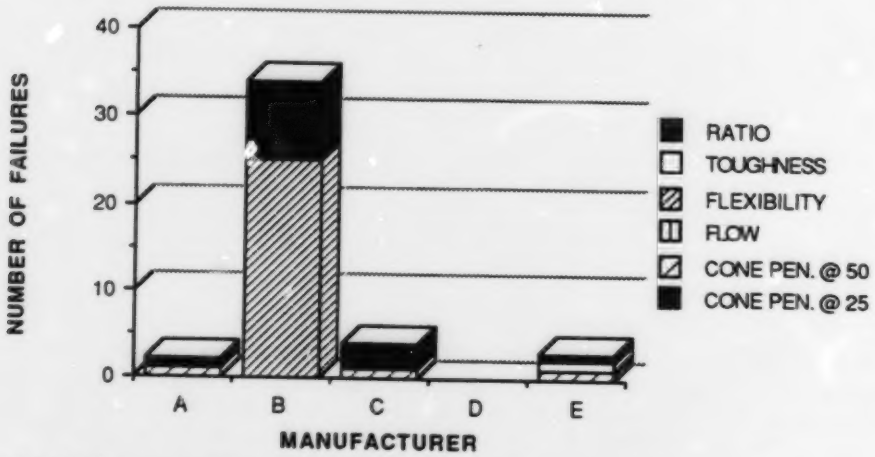
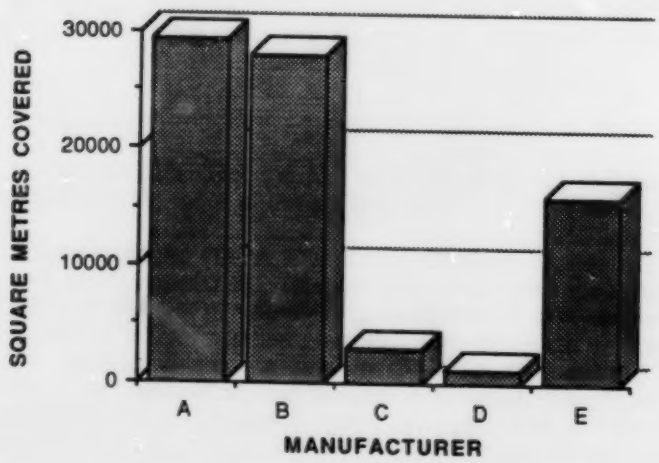


FIG. 6: MANUFACTURER'S SHARE OF AREA PLACED IN 1991



2.3 Material Mass Density

Although not a specification requirement, the mass density of each sample is determined in the laboratory. This mass density along with the other tests can be used to ascertain whether the sample is representative of the material as identified on the sample sheet. Since the various products have different mass densities, it is a useful tool to determine if a sample has been adulterated.

From the mass density of each product, the quantity required to cover a given area may be determined. Table 2 presents the quantity of product required to cover a square metre with 5 mm of membrane based on the mean mass density determinations of the five products supplied to the Ministry in 1991.

TABLE 2 : MATERIAL REQUIRED PER SQUARE METRE OF BRIDGE DECK (5 mm thick)

PRODUCT	kg/m^2
BAKOR, (BAKELITE) 790-11	6.00
BEMAC, BEMALASTIC 21-150	7.90
CRAFCO, 34551	5.70
HYDROTECH, 6120 BD	5.75
PERMAQUIK, 6100 BM	6.20

3 DISCUSSION

3.1 Material Thickness

The average lot thickness and lot standard deviation has remained static for the last five years. This suggests that these numbers are not likely to change much in the future. Any contractor attempting to reduce the quantity of material used (thinner membrane) will have to exercise a greater level of process control to avert the possibility of a price adjustment due to variability.

When the acceptance system was introduced in 1986, some contractors objected, saying that membrane thickness could not be controlled to such tight tolerances. The high level of compliance is testimony to the requirements being achievable with reasonable process control.

3.2 Material Quality

An analysis of the test data over the last eight years shows that about 20% of all material samples have failed one or more of the six test criteria. This is demonstrated in Figure 7.

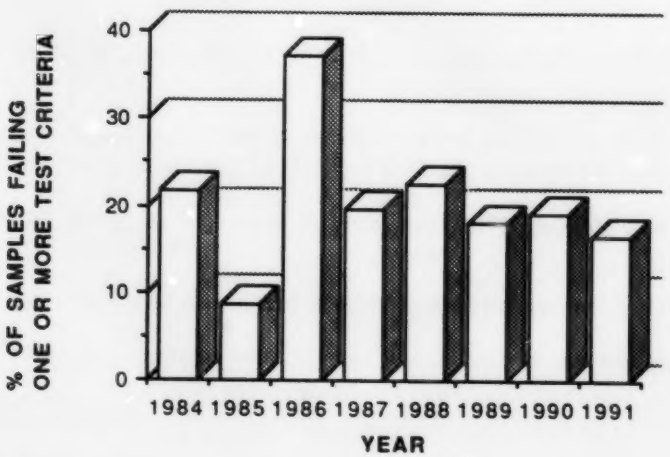
In 1986 the Ministry changed the requirement for cone penetration at 50° C from a maximum of 200 down to a maximum of 160. This was the most frequently failed criteria for the next five years. Failure of this test can sometimes be attributed to prolonged heating, overheating or reheating, in the contractor's kettle. In 1990, 16% of all the samples failed this requirement. In order to provide a greater incentive for the industry to comply with the requirements for cone penetration, the Ministry quadrupled the adjustment points for failure in contracts advertised after January 1, 1991. In 1990, 35% of manufacturer "A's" and 9% of manufacturer "E's" product failed the requirement for penetration at 50°C. In 1991, the

failure rates for this test by these two manufacturers dropped to 1% and 2% respectively. The incentive appears to have worked.

So why do we still have a 16% overall failure rate in 1991? The problem lies with manufacturer "B" who over the previous four years had an enviable quality history. Twenty nine of thirty seven failed samples (78%) were from manufacturer "B". An estimate of the deck area covered with this material is 9,312 m^2 (average lot size constructed with this product times 29 samples). At the end of July 1991, after noting a change in typical values for the product, the manufacturer was advised of the observation and that three recent samples of the 35 tested to date had failed the requirement for low temperature flexibility. The manufacturer committed themselves to increased quality control testing and gave assurance of their intent to consistently meet specification requirements. From the end of August to the end of October, a two-month period, a large number of lots were constructed with this product. However, due to staff shortages in the laboratory and other materials being given priority testing, only two samples of this product were tested in the month of September. By the time the samples from this two-month period were tested it was found that a full 64% of them failed; mostly low temperature flexibility and some, the toughness/peak force ratio. At this point, the Ministry placed a moratorium on the use of the product. Another contributor to the poor statistics for 1991 is the product supplied by manufacturer "C", which although was only used on seven lots, had a 57% failure rate. This manufacturer and the Ministry are currently looking to a resolution of the problem.

From the above scenario it can be clearly seen that timely testing is required in order to minimize the risk of having significant quantities of defective material incorporated into Ministry work. It is also evident that the manufacturers quality control operations were ineffective in detecting defective material.

FIG. 7: MANUFACTURERS' EIGHT-YEAR HISTORY



4 FIELD ADMINISTRATION

4.1 Material Thickness

Compilation of the Waterproofing Membrane Thickness Reports has improved over previous years but some are still received with missing information and/or incorrect computations.

The following are some of the most common errors:

a. Stages, rather than whole bridge decks, are divided into lots. This results in the same lot number appearing twice for one bridge,

b. The "brand" name of the membrane used is not recorded in the space for "Membrane",

c. The standard deviation is incorrectly rounded off. It should be rounded to the closest 0.05. Incorrect rounding can make a significant difference in the determination of the payment adjustment factor.

4.2 Material Quality

Many samples are received without the Concrete Products Field Sample Sheet being adequately completed. Field staff should refer to the "Field Guide For Acceptance Of Hot Mix and Bridge Deck Waterproofing", to make sure that all required information is provided with the sample. This information is critical to our data base and to assure that price adjustment is applied to the correct lot should a sample fail the quality tests.

Approximately 80% of the samples received at the laboratory were less than the required four litres.

5 CONCLUSION

The introduction of end result specifications for the acceptance of bridge deck waterproofing has had the desired impact of improving compliance to thickness requirements.

Field testing in 1991 indicates 98.6% of all lots met thickness requirements on the first assessment.

Laboratory testing shows 83.6% of all samples tested complied with materal quality requirements.

Quadrupling the adjustment points for failing the cone penetration tests has had the desired effect of substantially improving compliance to those requirements.

Timely material testing is imperative to avoid substantial quantities of defective material being incorporated in Ministry work.

Some manufacturers need to improve on their quality control proceedures.

There are continuing problems with contract administration and documentation.

6 RECOMMENDATION

Quality Assurance staff should review the acceptance procedures for bridge deck waterproofing with the Project Supervisor, with particular emphasis on computations and documentation prior to commencement of all waterproofing work.

Laboratory testing of waterproofing membrane should not be deferred to other materials exclusively but remain continuous albeit at a reduced rate in busy times.

1991 WATERPROOFING SUMMARY

CONTRACTOR	AVE. THICK.	AVE. ST. DEV.	SQ. METRES	TOTAL NUMBER OF LOTS	NUMBER OF BORDERLINE LOTS	NUMBER OF REJECTABLE LOTS	NUMBER OF MATERIAL SAMPLES	NUMBER OF MATERIAL FAILURES
F	4.75	0.73	363.4	2	0	0	2	0
B	4.85	0.75	971.6	2	1	0	2	1
C	5.03	0.53	2,495.8	12	0	0	10	2
E	5.16	0.68	10,697.4	25	0	0	25	1
H	4.89	0.65	11,393.6	48	2	0	51	13
D	4.70	0.59	11,620.9	26	0	0	29	4
A	4.93	0.68	17,700.6	42	0	0	39	14
G	4.87	0.60	22,216.0	65	0	0	66	2
		TOTAL	77,459.3	222	3	0	224	37

MANUFACTURER	AVE. THICK.	SQ. METRES	NUMBER OF SAMPLES TESTED	NUMBER OF SAMPLES FAILED	FAILED CONE PEN. @ 25 C	FAILED CONE PEN. @ 50 C	FAILED FLOW	FAILED FLEXIBILITY	FAILED TOUGHNESS	FAILED RATIO
D	4.90	1,245.9	5	0	0	0	0	0	0	0
C	4.66	2,927.0	7	4	0	1	0	0	0	3
E	4.89	15,830.7	52	2	0	1	0	0	1	1
B	4.92	28,111.8	88	29	0	0	0	25	0	9
A	4.92	29,343.9	73	2	0	1	0	0	0	1
	TOTAL	77,459.3	225	37	0	3	0	25	1	14